Thermo-Acoustical and Molecular Interaction Studies in Binary Liquid Mixtures at Different Temperatures

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Abstract

Densities, viscosities and speeds of sound of the binary mixture of Benzyl benzoate with different mole fractions of N,N Di methyl formamide (NN DMF) have been measured using the standard techniques at 303.15, 308.15 and 313.15K. From the experimental data, various acoustical parameters such as isentropic compressibility (K_s), intermolecular free length (L_f), molar volume (V_m), Gibbs free energy (ΔG), Enthalpy (H^E)and their excess values like V_m^E, K_s^E, L_f^E, ΔG^E and H^E are evaluated . The computed values have been fitted to the Redlich–Kister type polynomial equation using least squares method to estimate the binary coefficients and standard deviations. Further, various empirical relations were used to correlate viscosity and speed of sound theories of these binary mixtures at different temperatures, over whole mole fraction range. Deviations of excess properties have been explained in terms of interactions between unlike components of the present binary system.

Keywords - *Acoustical parameters, Molecular interactions, Redlich–Kister type polynomial equation, viscosity and speed of sound theories, Mole fraction*

I. INTRODUCTION

Benzyl benzoate($C_6H_5CH_2O_2CC_6H_5$) is one of the older preparations used to treat scabies. Scabies is a skin infection caused by the mite sarcoptes scabie. It has vasodilating and spasmolytic effects and is present in many asthma and whoopin cough drugs. It is also used as an excipient in some testosterone-replacement medications for treating hypogonadism. Benzyl benzoate is used in non medical field as a repellent for chiggers, ticks, and mosquitoes. It is also used as a dye carrier, solvent for cellulose derivatives, plasticizer, and fixativein the perfume industry.

NN, Dimethylformamide is an organic compound with the formula$(CH_3)_2NC(O)H$. Commonly abbreviated as NNDMF (although this initialism is sometimes used for dimethylfuran, or dimethyl fumarate), this colourless liquid is miscible with water and the majority of organic liquids. NNDMF is a common solvent for chemical reactions. Dimethylformamide is odorless whereas technical grade or degraded samples often have a fishy smell due to impurity of dimethylamine.

The measured density, viscosity and speed of sound values were used to calculate the excess properties are fitted to the reduced Redlich-Kister (R-K) equations, through the Legendre polynomials, and are interpreted in terms of molecular interactions and structural effects [1-7].

Similar kinds of results were obtained by earlier papers [17-18] an increasing variety of research techniques are being employed to get an insight into the molecular behavior of liquids. Theoretical evaluation of ultrasonic velocity in binary liquid mixtures and its comparison with the experimental values reflects the molecular interaction in liquid mixtures, which is very useful to build comprehensive theoretical models for liquids. Several researchers[8-11] carried out investigations on liquid mixtures and correlated the experimental results of ultrasonic velocity with the theoretical relations of nomoto (NOM)[16], vandael and vangel (VDV)[19], jungie (JUN)[20], impedance (IMP)[21], ideal mixing relation (IMR) and rao's specific velocity (RAO) relation[22] . The validity of the theories was checked by applying the chi-square test (χ) for goodness of fit and by calculating the average percentage error (APE) for the binary system of Benzyl benzoate with NNDMF[23-25] at different mole fractions and the results are explained and discussed in terms of molecular interactions present in the investigated systems.

Table 01: Purity analysis

Chemical name	*CAS number*	*Source*	*Initial mole fraction*	*Purification method*	*Final mole fraction*	*Analysis method*
		Hi Media				

Benzyl benzoate	120-51-4	Laboratories Pvt. Ltd. Mumbai, India	0.99	Distillation	0.995	G L C
NNDMF	68-12-2	Sisco Laboratories Pvt. Ltd. New Delhi, India	0.99	Distillation	0.997	G L C

Gas liquid chromatography

II. EXPERIMENTAL

The binary liquid mixtures were prepared just before start the experiment for different samples with the help of mass variation. The uncertainty in the final mole fraction was estimated to be less than ±0.0001.

The speed of sound was measured at 303.15K to 313.15K using ultrasonic interferometer (M/s Mittal Enterprises, India) operating at a fixed frequency of 2 MHz with an accuracy of ±0.1m/s. for the binary systems of benzyl benzoate with formamide, NMF and DMF. The uncertainty in the speed of sound was found to be ±0.3 m s^{-1}.

The densities of the pure components and their multi components were measured with 10 mL specific gravity bottle in high accurate digital electronic balance (Baijnath Premnath SF 400A, Kanpur, U.P) with an accuracy of ±0.02 mg. The uncertainty in the measured density was ±0.001 kg m^{-3}.

The viscosities were measured with Ostwald viscometer. The viscometer was calibrated at different temperatures using redistilled water. The flow time has been measured after the attainment of bath temperature by each pure compound and mixture. The flow time has been measured with an electronic stop watch (Winner digital stopwatch W-999, Ravi scientific industries, New delhi, India) with a precision of ± 0.01 s. The uncertainty in viscosity measurement is up to ± 0.003 mPa s.

In all the measurements, the temperature was maintained by circulating water from an electronically controlled thermostatic bath manufactured by (M/s Mittal Enterprises, New Delhi) to an accuracy of +0.01 K. The precision of experimental measured values of density, viscosity and speed of sound data was compared with their literature values and uncertainties are shown in **Table 02**.

Table 02:Comparison of experimental densities (ρ), viscosities (η) and speed of sound (U) of pure liquids with literature values.

Liquid	*Temp T (K)*	*Density(ρ)kg m^{-3}*		*Viscosity(η)kgm^{1}s^{-1}*		*Speed of sound(U)m.s^{-1}*	
		lit	*expt*	*lit*	*expt*	*lit*	*expt*
Benzyl benzoate	303.15	1.1193[a]	1.1192	6.532[a]	6.554	1506.0[a]	1504.0
	308.15	1.1145[b]	1.1142	6.261[b]	6.223	1493.1[b]	1495.4
	313.15	1.1097[a]	1.1094	5.021[a]	5.020	1471.4[a]	1473.2
NNDMF	303.15	0.9397[c]	0.9508	0.757[c]	0.770	1440.0[c]	1437.6
	308.15	0.9368[c]	0.9388	0.707[c]	0.732	1426.0[c]	1417.0
	313.15	0.9298[c]	0.9300	0.664[c]	0.681	1404.0[c]	1400.2

Standard uncertainties 'U' are U(X_1) =0.0001, U (ρ) = 0.001 kg.m^{-3}, U (η) = 0.003 mPa.s, U (u) = 0.3 m.sec^{-1}

[a] Reference [23] [b] Reference [24] [c] Reference[25]

III. THEORY

A. Excess parameters

The deviations of experimental values from the ideal mixtures are explained with excess thermo-acoustical parameters. The excess molar volume (V^E), excess isentropic compressibility (K_s^E), excess free length, (L_f^E), excess Gibbs free energy of activation (ΔG^{*E}) and excess Enthalpy (H^E) have been calculated by using the following relation

$$V^E = \frac{X1M1+X2M2}{\rho} - \left(\frac{X1M1}{\rho 1} + \frac{X2M2}{\rho 2}\right) \quad (1)$$

Where ρ is the density of the mixture and X_1 , M_1, and ρ_1 and X_2, M_2, ρ_2 are the mole fraction, molar mass and density of pure components 1 and 2, respectively.

$$K_s^E = K_s - K_s^{id} \quad (2)$$

Where K_s^{id} is the ideal isentropic compressibility value & K_s represent the calculated value of isentropic compressibility for the mixture.

K_s^{id} for an Ideal mixture was calculated using the relation recommended by Benson & Kiyohara[32].

$$K_s^{id} = \sum \emptyset i \left\{ Ks, i^{o} + \frac{TVi^{o}(\grave{\alpha}i^{0})2}{Cp,i^{o}} \right\} - T(\sum Xi\, Vi^{o}) \left(\frac{\sum \emptyset i \grave{\alpha} i^{o},2}{\sum Xi\, Cp,i^{o}} \right) \quad (3)$$

In which $K_{s\ i}^{o}$, $V^{i}o$, $\grave{\alpha}_i^{o}$, $C_{p,j}^{o}$ are the isentropic compressibility, molar volume, isobaric thermal expansion coefficient and molar isobaric heat capacity of pure component i, T represents temperature and ϕ_i is volume fraction

$$L_f^{E} = L_f - K_T (K_s^{id})^{1/2} \quad (4)$$

Where L_f represents the calculated value for the mixture and K_T represent a temperature dependent constant whose values is $K_T = (91.368 + 0.3565\ T) \times 10^{-8}$.

$$\Delta G^{*E} = RT \left[\ln \left(\frac{\eta V}{\eta_2 V_2} \right) - x_1\ ln \left(\frac{\eta_1 V_1}{\eta_2 V_2} \right) \right] \quad (5)$$

Where R represents gas constant, T is absolute temperature, η is the viscosity of the mixture and η_1, η_2 are the viscosities of the pure compounds, V is the molar volume of mixtures and V_1,V_2 are the molar volumes of the pure compounds.

$$H^{E} = H-(X_1H_1 + X_2H_2) \quad (6)$$

Where H represents the calculated value of enthalpy for the mixture and H_1, H_2 represents enthalpy of pure components 1 and 2, respectively.

The excess values for the above parameters were fitted by the method of nonlinear Least – squares to a Redlich- Kister type polynomial,

$$Y^{E} = x_1\ (1\text{-}x_1) \sum_{i=1}^{n} A_i\ (2\ x_1 - 1)^{\,i-1} \quad (7)$$

Where Y^{E} = Ks^{E}, V^{E}, ΔG^{*E}, H^{E}. The values of coefficient A_i were determined by a regression analysis based on the least- squares method and presented in the Table 4.

B. Speed of Sound theories

The speed of sound is also calculated by using the following empirical relations as available in the literature.

Nomoto derived a relation to evaluate speed of sound for a multi component liquid solution ,

$$U_{NOM} = [X_1R_1 + X_2R_2 / X_1V_1 + X_2V_2]^3 \quad (8)$$

where R = V.U and V = M_{eff} /η. X, R and V are the mole fraction, molar sound velocity and molar volume of the mixture.

Jungie has also derived a relation for the determination of speed of sound for the multi component mixtures that can be expressed as [20]

$$U_{JM} = [X_1V_1 + X_2V_2 / (X_1m_1 + X_2m_2)^{1/2}][X_1V_1 / d_1U_1^{2} + X_2V_2 / d_2U_2^{2}]^{-1/2} \quad (9)$$

Where X, d, U and V are the mole fraction, density, speed of sound and molar volume of the mixture.

The sound speed in the mixture is given by Impedance dependence relation and can be expressed as

$$U_{IMP} = X_1Z_1 + X_2Z_2 / X_1\rho_1 + X_2\rho_2 \quad (10)$$

Where X, ρ and Z are the mole fraction, density and acoustic impedance of the mixture.

On the basis of assumptions made by Blandermer and Waddington, Vandael and Vangel expressed the following relation for speed of sound in liquid mixtures

$$U_{VDV} = [1/X_1m_1 + X_2m_2]1/2[X_1/m_1U_1^{2} + X_2/m_2U_2^{2}]^{-1/2} \quad (11)$$

Where X, m and U are the mole fraction, effective molecular weight and speed of sound of the mixture

Rao's relation is also used to measure the specific sound velocity for liquid mixtures is as follows

$$U_R = (R/V)^{3} \quad (12)$$

Where R, V are the Rao's specific sound velocity and molar volume of the mixture

The validity of the all the theories is checked by applying Chi-square test and by calculating average percentage error (APE), the relations are as follows:

$$APE = [(1/(n) \sum 100(Uexp - Ucal)/Uexp)\ ] \times 100\% \quad (13)$$

$$\text{Chi square } (\chi) = \sum_{i=1}^{n} (Uexp\text{- Ucal})^2 /Ucal)\ ] \quad (14)$$

Where, *n*- number of data used

C. Partial molar volumes

The partial molar volumes for all the binary systems can be calculated using the formulae

$$V^{*}_{m,1} = V^{E}_{m} + V_{1\ +} X_2 \left(\frac{\partial VEm}{\partial x} \right)_{P,T} \quad (15)$$

$$V^{*}_{m,2} = V^{E}_{m} + V_{2\ +} X_1 \left(\frac{\partial VEm}{\partial x} \right)_{P,T} \quad (16)$$

Where $V^{*}_{m,1}$ and $V^{*}_{m,2}$ are the partial molar volumes and V_1 and V_2 molar volumes of pure compounds.

The values of infinite dilution of partial and excess partial molar volumes ($V^{*E,\infty}_{m,1}$,$V^{*E,\infty}_{m,2)}$ for the binary liquid system can be calculated by the following relations.

$$V^{*E,\infty}_{m,1} = A_0 + A_1 + A_2 + A_3 + \text{- - - - - - - } = V^{\infty}_{m,1} - V_1 \quad (17)$$

$$V^{*E,\infty}_{m,2} = A_0 - A_1 + A_2 - A_3 + \text{- - - - - - - } = V^{\infty}_{m,2} - V_2 \quad (18)$$

Where A_0, A_1, A_2, A_3 are the coefficients obtained from R-K polynomial equation are tabulated in table 4.

IV. RESULTS AND DISCUSSIONS

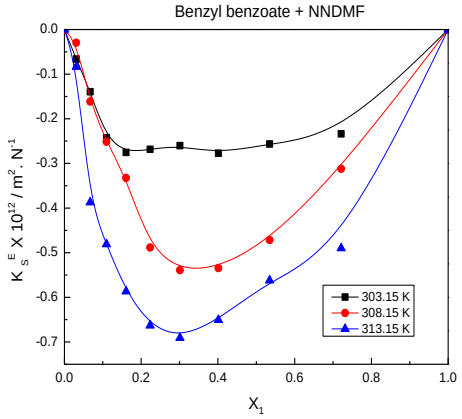
Speeds of sound, density and viscosity have been measured using the standard techniques in the binary mixtures of Benzyl benzoate + Di methyl formamide [N, NDMF] from 303.15 K to 313.15K temperatures are given at table 3.

Table 03: Experimental values of Density (ρ), Viscosity(η) and Speed of sound(U) for Benzyl benzoate with NNDMF

X_1	Density (ρ)	Speed of Sound(U)	Viscosity (η)	X_1	Density (ρ)	Speed of Sound(U)	Viscosity(η)
			303.15 K				
0.0000	0.9388	1417.0	0.7326	0.3011	1.0677	1460.8	3.0591
0.0309	0.9462	1420.6	1.2140	0.4013	1.0889	1466.8	4.3652
0.0670	0.9752	1423.6	1.6938	0.5347	1.1010	1476.8	4.7376
0.1096	0.9880	1429.0	1.8377	0.7211	1.1073	1485.8	5.0486
0.1607	1.0005	1432.4	2.2146	1.0000	1.1108	1490.2	6.1044
0.2232	1.0376	1457.4	2.3980				
			308.15 K				
0.0000	0.9388	1417.0	0.7326	0.3011	1.0677	1460.8	3.0591
0.0309	0.9462	1420.6	1.2140	0.4013	1.0889	1466.8	4.3652
0.0670	0.9752	1423.6	1.6938	0.5347	1.1010	1476.8	4.7376
0.1096	0.9880	1429.0	1.8377	0.7211	1.1073	1485.8	5.0486
0.1607	1.0005	1432.4	2.2146	1.0000	1.1108	1490.2	6.1044
0.2232	1.0376	1457.4	2.3980				
			313.15K				
0.0000	0.9300	1400.2	0.6809	0.3011	1.0745	1448.0	3.9703
0.0309	0.9430	1409.0	1.5464	0.4013	1.0915	1453.2	3.8377
0.0670	0.9803	1419.2	1.8741	0.5347	1.0952	1463.6	4.1430
0.1096	1.0048	1423.4	2.7121	0.7211	1.1012	1471.0	4.5620
0.1607	1.0262	1434.4	2.8875	1.0000	1.1028	1475.2	5.0500
0.2232	1.0512	1442.2	3.7246				

Standard uncertainties 'U' are $U(X_1)$ =0.0001, U (ρ) = 0.001 $kg.m^{-3}$, U (η) = 0.003 mPa.s, U (u) = 0.3 $m.sec^{-1}$

Graphs for variation of excess thermo-acoustic properties with respect to mole fraction(X_1) at various temperatures (303.15K, 308.15K and 313.15K) for Benzyl benzoate + NNDMF system have been calculated by using equations (1) to (6) and presented in the figure 1 to 5.The values observed for K_s^E, V^E, L_f^E, G^E and H^E can be explained from several effects depending upon the physical, chemical and geometrical nature of the present components of the studied binary system.[12-15].



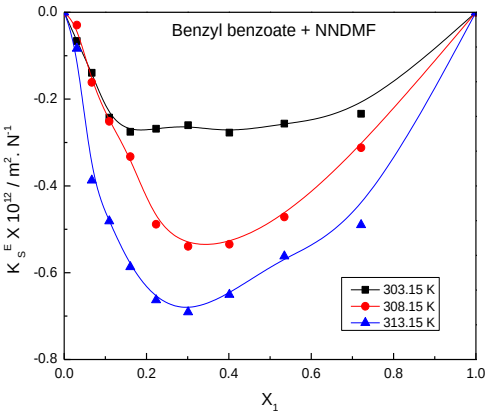


Fig. 1. Variation of excess isentropic compressibity with respect to mole fraction of benzylbenzoate + NNDMF at three different temperatures

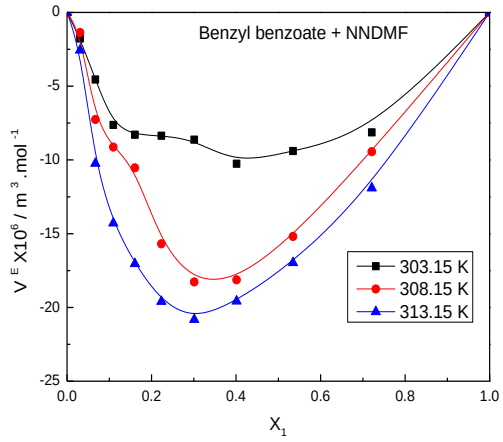


Fig 2. Variation of excess molar volume with respect to mole fraction of benzyl benzoate +NNDMF at three different temperatures

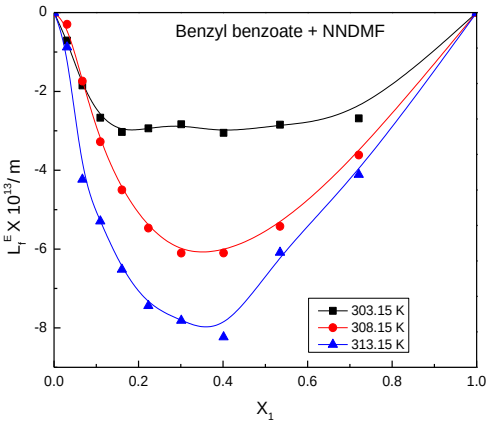


Fig. 3. Variation of excess free length with respect to mole fraction of benzylbenzoate + three different temperatures

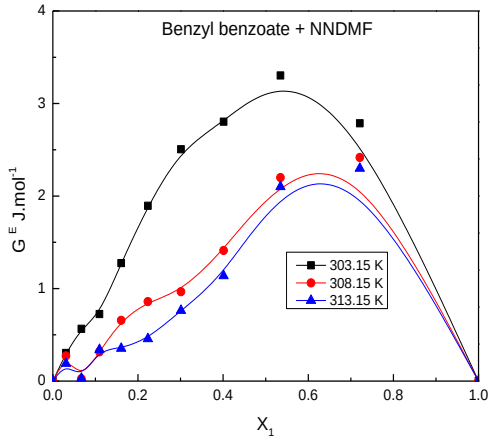


Fig 4. Variation of excess gibbs free energy with respect to mole fraction of benzyl benzoate + NNDMF at NNDMF at three different temperatures

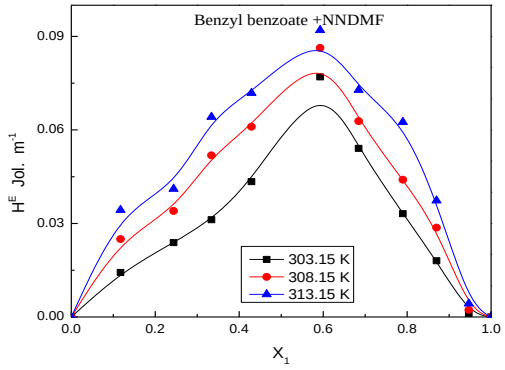


Fig. 5. Variation of excess enthalpy with respect to mole fraction of benzylbenzoate + NNDMF at three different temperatures

The variation of excess excess isentropic compressibility with the mole fraction for benzyl benzoate with NNDMF ranging from 0 to 1 at different temperatures is as shown in Fig-1. From Fig. 1. it is observed that the excess isentropic compressibility(K_s^E) values are negative for the entire mole fraction range. The negative values of excess excess isentropic compressibility suggest that there exist strong interactions between the components of liquid mixture which is supported by SheoPrakash et al[29].Fig. 2 represents the variation of excess molar volume (V^E) with the mole fraction for benzyl benzoate with NNDMF ranging from0 to 1 at different temperatures. Negative variations for mole fraction range. The negative variations, confirm that there exist dispersion and dipolar forces in the components of liquid mixtures .

The variation of excess free length (L_f^E)with respect to the mole fraction for benzyl benzoate with NNDMF ranging from 0 to 1 at different temperatures is as shown in Fig. 3.The variation of excess gibbs free energy(ΔG^E) with respect to the molefraction for benzyl benzoate with NNDMF ranging from 0 to 1 at different temperatures is as shown in Fig. 4 and the variation of excess enthalpy(H^E) with respect to the mole fraction for benzyl benzoate with NNDMF ranging from0 to 1 at different temperatures is as shown in Fig. 5.For both Fig 4 &5 gives positive variation. The positive variations suggest that there exist weak interactions between the components of liquid mixture .It is observed that there exist specific strong molecular interactions between the components of the liquid mixtures [26, 27].

Table 04 Parameters (A_k) and Standard Deviation (σ) for Benzyl benzoate with NN DMF at T= 303.15 K, 308.15K and 313.15K

parameter	Temperature (K)	A0	A1	A2	σ
	303.15	0.0396	-0.0536	0.2584	0.0015
H^E	308.15	0.0217	-0.0765	0.2003	0.0022
	313.15	0.0289	-0.0399	0.2257	0.0017
	303.15	-33.6980	7.2776	-62.4457	6.8137
V^E	308.15	-60.5201	64.9931	-0.1572	11.1080
	313.15	-61.9072	56.8615	-89.2960	13.6648
	303.15	13.1879	-1.4292	-4.0121	1.7884
ΔG^E	308.15	8.6836	6.4892	2.2236	1.1080
	313.15	7.9171	7.8270	2.5008	0.9945
	303.15	-0.8878	0.1501	-2.4629	0.2191
K_s^E	308.15	-1.9487	1.9332	0.5760	0.3458
	313.15	-2.1218	1.1586	-4.1729	0.4809
	303.15	-9.6210	0.1792	-30.6961	2.2793
L_f^E	308.15	-22.0496	21.7394	2.7124	3.8948
	313.15	-23.2002	25.9389	-29.8710	5.2351

Fitting the parameters and standard deviations (σ) of Equation (7) for the least-squares representation various excess parameters like H^E,V^E,ΔG^E ,K_s^E and L_f^E for benzyl benzoate with NNDMF .The coefficients A_i and the corresponding deviations σ are obtained from RK polynomial equation are given in Table 4**.**

The molecular interactions between the components of liquid mixtures shows the non-ideal nature . Non-ideal liquid mixtures show considerable deviation from linearity in their physical behavior with respect to concentration and these have been interpreted as arising from the presence of strong or weak interactions.

Table: 5 Partial molar volumes for Benzyl benzoate with NNDMF at different temperatures

The obtained values of partial molar volumes are reported in table 5, also tabulated the infinite dilution values of partial molar volume and Excess partial molar volumes in table 6.

The excess partial molar volumes for whole mole fraction of all binary mixtures are shown from fig 7-8 it is seen that the values are negative, from which it concludes that strong interactions exist among the taking liquid mixtures.

Mole fraction (X1)	Partial molar Volumes		Mole fraction (X1)	Partial molar Volumes	
	$V^*_{m,1}$	$V^*_{m,2}$		$V^*_{m,1}$	$V^*_{m,2}$
		303.15 K			
0.0000	11.8524	23.5554	0.3011	15.1821	15.8817
0.0309	21.6321	21.8327	0.4013	14.9264	14.6264
0.0670	20.9692	20.4688	0.5347	12.4609	12.1608
0.1096	19.6454	19.1436	0.7211	10.6682	10.2674
0.1607	18.6178	18.6103	1.0000	8.5302	7.5301
0.2232	17.0892	17.8744			
		308.15 K			
0.0000	20.6349	24.6347	0.3011	16.2167	16.2166
0.0309	21.4868	21.6864	0.4013	14.4470	14.4468

0.0670	20.9822	20.1819	0.5347	12.4903	12.4901
0.1096	20.3108	20.4107	0.7211	10.0811	10.0810
0.1607	18.5408	18.5609	1.0000	7.9649	8.8447
0.2232	17.7251	17.7251			
		313.15 K			
0.0000	21.6749	23.9248	0.3011	16.3238	16.3235
0.0309	22.0919	22.0920	0.4013	14.7362	14.6362
0.0670	21.1550	21.1547	0.5347	12.7514	12.7413
0.1096	19.7537	19.7529	0.7211	10.1486	10.1481
0.1607	18.6067	18.6056	1.0000	6.6311	7.6617
0.2232	17.3527	17.3520			

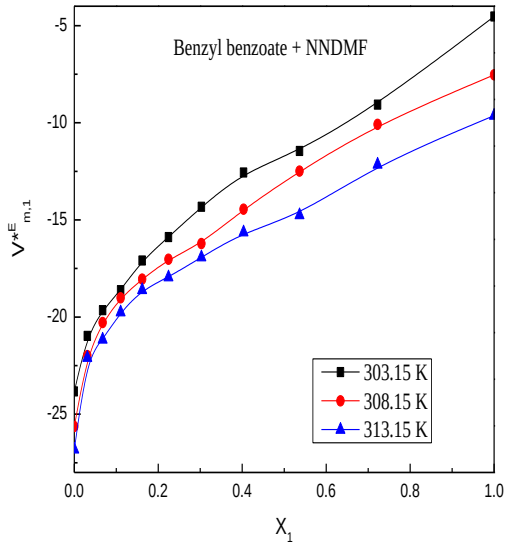


Fig.6 Variation of **excess partial molar volume** ($V^{*E}_{m,1}$) with respect to mole fraction of benzyl benzoate + NNDMF at three different temperatures

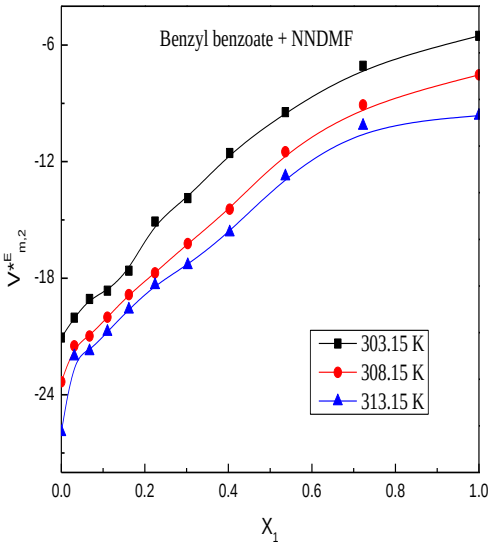


Fig.7 Variation of **excess partial molar** ($V^{*E}_{m,2}$)with respect to mole fraction of benzyl benzoate + NNDMF at three different temperatures

Table 06 Values of partial molar volume of the components at infinite dilution ($V^{\infty}_{m,1}$, $V^{\infty}_{m,2}$) and excess partial molar volume at infinite dilution ($V^{E,\infty}_{m,1}$and $V^{E,\infty}_{m,2}$) for all the systems at three different temperatures

System	*Temperature*	$V^{*\infty}_{m,1}X10^{-5}$	$V^{*\infty}_{m,2}X10^{-5}$	$V^{*E,\infty}_{m,1}X10^{-5}$	$V^{*E,\infty}_{m,2}X10^{-5}$
Benzyl benzoate	303.15 K	11.8524	7.5301	4.682	4.683
+NNDMF	308.15 K	20.6349	8.8447	0.246	0.124
	313.15 K	21.6749	7.6617	0.302	0.502

Further, the experimental values of speed of sound along with their theoretical values with mole fraction in the binary liquid mixtures of benzyl benzoate with NNDMF at temperatures 303.15 K, 308.15 K and 313.15K are given at table 7 and the average percentage error (APE) and chi square test (χ) is also included for the individual binary systems.

Table 07: Experimental values of Speed of sound theories for the binary system of Benzyl benzoate with N,N DMF at T= 303.15 K, 308.15K and 313.15K

X_1	U_{EXP} $m.s^{-1}$	U_{NOM} $m.s^{-1}$	U_{IMR} $m.s^{-1}$	U_{IMP} $m.s^{-1}$	U_{JM} $m.s^{-1}$	U_{VDV} $m.s^{-1}$	U_R $m.s^{-1}$
			303.15 K				

0.0000	1437.6	1437.6	1437.6	1437.6	1437.6	1437.6	1437.6
0.0309	1445.2	1438.2	1416.4	1439.9	1437.8	1416.4	1473.7
0.0670	1455.4	1438.9	1394.6	1442.6	1438.1	1394.6	1535.4
0.1096	1460.6	1439.7	1372.4	1445.8	1438.5	1372.4	1612.5
0.1607	1469.0	1440.9	1350.1	1449.5	1439.1	1350.1	1638.5
0.2232	1474.4	1442.4	1328.8	1453.9	1439.8	1328.8	1653.6
0.3011	1479.8	1444.5	1309.9	1459.3	1440.9	1309.9	1680.6
0.4013	1483.6	1447.7	1296.9	1465.9	1442.7	1296.9	1767.4
0.5347	1492.6	1453.2	1297.9	1474.5	1446.2	1297.9	1795.1
0.7211	1498.8	1464.5	1335.1	1485.7	1455.1	1335.1	1850.0
1.0000	1501.2	1501.2	1501.2	1501.2	1501.2	1501.2	1501.2
APE		0.0014	0.0065	0.0008	0.0016	0.0065	-0.0098
Chi square		0.0154	0.0714	0.0088	0.0174	0.0714	-0.1079
			308.15 K				
0.0000	1417.0	1417.0	1417.0	1417.0	1417.0	1417.0	1417.0
0.0309	1420.6	1417.7	1396.9	1419.7	1417.3	1396.9	1444.1
0.0670	1423.6	1418.5	1376.2	1422.7	1417.8	1376.2	1572.2
0.1096	1429.0	1419.5	1355.1	1426.3	1418.3	1355.1	1623.5
0.1607	1432.4	1420.8	1334.0	1430.5	1419.1	1334.0	1670.8
0.2232	1457.4	1422.6	1313.7	1435.6	1420.1	1313.7	1841.4
0.3011	1460.8	1425.0	1296.0	1441.7	1421.6	1296.0	1973.0
0.4013	1466.8	1428.8	1284.1	1449.4	1424.0	1284.1	2040.9
0.5347	1476.8	1435.1	1286.1	1459.2	1428.4	1286.1	2023.2
0.7211	1485.8	1448.1	1324.1	1472.2	1439.2	1324.1	1893.3
1.0000	1490.2	1490.2	1490.2	1490.2	1490.2	1490.2	1490.2
APE		0.0012	0.0062	0.0005	0.0014	0.0062	-0.0173
Chi square		0.0136	0.0681	0.0060	0.0155	0.0681	-0.1898
			313.15 K				
0.0000	1400.2	1400.2	1400.2	1400.2	1400.2	1400.2	1400.2
0.0309	1409.0	1400.9	1380.6	1402.9	1400.6	1380.6	1453.0
0.0670	1419.2	1393.9	1353.7	1398.7	1393.1	1353.7	1611.0
0.1096	1423.4	1395.0	1333.8	1402.8	1393.8	1333.8	1722.8
0.1607	1434.4	1396.5	1313.9	1407.5	1394.6	1313.9	1818.9
0.2232	1442.2	1398.5	1294.9	1413.3	1395.8	1294.9	1931.8
0.3011	1448.0	1401.3	1278.4	1420.3	1397.5	1278.4	2029.1
0.4013	1453.2	1405.5	1267.7	1428.9	1400.3	1267.7	1643.1
0.5347	1463.6	1412.7	1270.7	1440.1	1405.4	1270.7	1593.5
0.7211	1471.0	1427.4	1309.5	1454.8	1417.7	1309.5	1503.4
1.0000	1475.2	1475.2	1475.2	1475.2	1475.2	1475.2	1475.2
APE		0.0016	0.0065	0.0009	0.0018	0.0065	-0.0210
Chi square		0.0175	0.0714	0.0096	0.0195	0.0714	-0.2315

From this table, The Chi-square value and the average percentage error values are small. On comparison, the Nomoto relation and jungie relation are found to give some valuable estimate of the experimental values of speed of sound values in these mixtures. The predictive abilities of various speeds of sound theories depend upon the strength of interaction prevailing in a system[28,30]. The extent of deviation may be attributed to the assumptions made in these theories for the polar- polar and non polar-non polar interaction

between the molecules entire mole faction range. Therefore, no interaction between the components of liquid mixtures has been taken into account.

The assumption for the formation of ideal mixing relation is that the ratio of specific heats of ideal mixtures and the volumes are also equal, the molecules are treated as real non elastic substances. But the interaction between the molecules of the binary liquid mixture takes place because of presence of various types of forces such as charge transfer and dipole-induced dipole interactions. Hence the observed deviation shows that the molecular interaction is taking place between the unlike molecules in the liquid mixture. This suggests the existence of strong tendency for the association between components [31, 33]. The deviations of theoretical values from the experimental one is due to the presence of molecular interaction, interstitial accommodation as molecules have different sizes and shapes and orientation of molecules etc.

V. FT-IR SPECTRA

The FT-IR spectra of pure solvents and their mixtures have been done in the wave number region (cm^{-1}) to percentage of Transmittance. Some representative spectra are given in the fig. 8-9. The shifting frequency of different amides in Benzyl Benzoate is also due to breaking of intra as well as inter molecular hydrogen bonding present in the amides and formation of the same between the unlike molecules in the liquid mixtures.

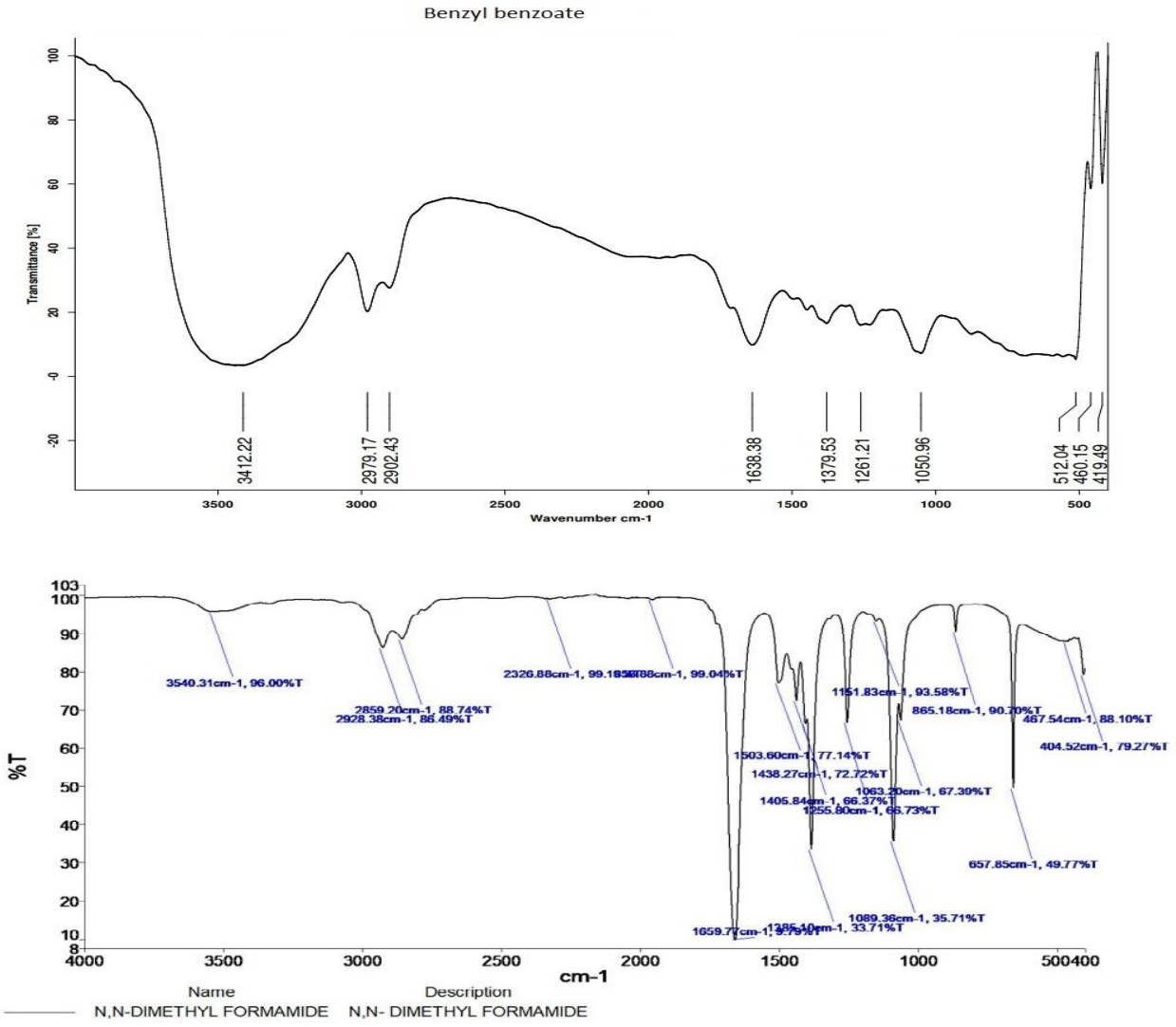


Fig 08 FTIR analysis for pure components of benzyl benzoate and NNDMF

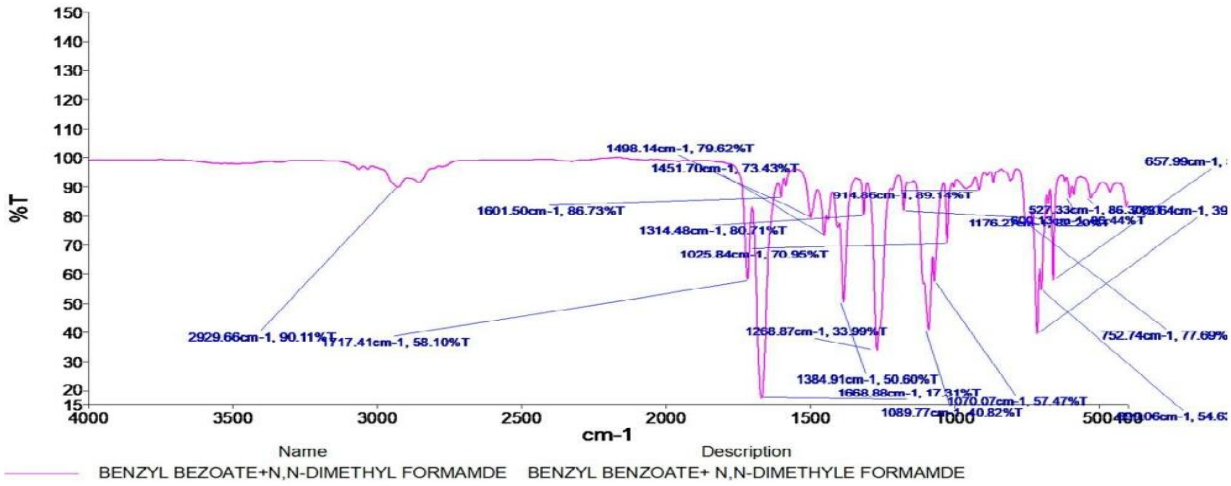


Fig 09 FTIR analysis for the binary liquid mixtures of benzyl benzoate with NNDMF

VI. CONCLUSIONS

The experimental values of speed of sound, densities and viscosities of binary mixtures for benzyl benzoate with NNDMF were determined as function of composition at temperature 303.15K, 308.15K and 313.15K. Using these data, various thermo acoustical parameters were computed by using the standard relations obtained from the literature. The excess enthalpy and gibb's free energy values are found to be positive and the values of excess properties V^E, K_s^E and L_f^E are found to be negative for binary mixture of BB with N, NDMF in the whole mole fraction range at the three different temperatures **.**Further the value of the excess parameters is fitted to the Redlich-Kister polynomial equation and the results are also presented. The speed of sound values of the binary mixtures were correlated by various theoretical equations and presented with the experimental values. Moreover, FT-IR analysis of the pure solvent and their mixtures are also reported.

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